Targeting SLM technologies across landscapes: a framework to facilitate matching SLM technologies with landscape conditions and generate evidences

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SUMMARY

The aim of this report is to develop a detailed framework that can guide the placement of land restoration options where they can be more effective so that the right 'places' are targeted and the appropriate technologies are used. The framework will also form the basis towards developing a decision support tool that can be used to accomplish processes and steps of landscape restoration (Fig. 1). The framework details the steps from diagnosis to identify hotspot areas of intervention, characterize those hotspots to assess potentials, constraints and current status. Once the detailed characterization is done, the next level will be to identify suitable SLM options that can be applied to restore the conditions of the hotspots. In order to make sure that the practices/technologies can serve their purpose there will be a need to characterize them in terms of their potential and requirements. Once the above two are assessed, ex-ante and scenario analysis can be undertaken to evaluate the impacts of the interventions across the landscape catena. This is an essential step to gain an idea of what we will get from implementing the technologies targeting the hotspots. Once this preliminary information is available, we can match the options (LSM technologies/practices) to context (diagnosed hotspots). This is the actual development work on the ground and should be led by the results of the scenario analysis – implement linked/complementary technologies following the landscape continuum. The next step will then be to generate evidences of the interventions using before/after and/or with and without approaches. This is equally important because this is the step where we determine whether the interventions are providing the intended services and functions. Based on lessons, adjustments can be made where necessary. This can be done in near real-time so that incentives can be provided or penalties can be enforced. Tradeoff analysis will also be a key component of this step. Finally, it will be necessary to determine the optimum combinations of land uses and management options to gain optimum benefits in terms of ecosystem services.

INTRODUCTION

Land degradation is a very serious problem in Ethiopia, with a cost of 4.6 billion per year (Gebreselassie et al., 2016). This prompted the government to give landscape restoration and sustainable land management (SLM) top priority. Tremendous land restoration efforts have been implemented some estimates indicating an investment amount of 1.2 billion per year (Adimassu et al., 2017). The country has also pledged to restore over 15 million ha by 2025 as part of the Bonn Challenge which has increased to 22 million during the New York declaration.

Various strategies exist for designing and targeting land management options (Tran et al., 2020). Natural resources management (NRM) technologies through watershed/landscape approach have often been implemented using Community Based Participatory Watershed Development (CBPWD) guideline (Lakew Desta et al., 2005). This guideline was broadly designed on the basis of agro-ecology, slope gradient and land use as criteria for technology targeting. This was built on local experiences without being complemented by research and multi-disciplinary experts' views. Practical experiences and case studies have proven a lack of appropriate selection and placement of SLM technologies in a given farm or landscape (Ebabu et al., 2019; Martínez-Mena et al., 2020). Selection and placement as well as the scaling up of NRM technologies and strategies have been constrained with inadequate knowledge about the detailed characteristics of local agro-ecological and climatic factors (rainfall), topographic conditions (slope gradient, landform and landscape topographic index/transmissivity), soil characteristics (soil texture, soil depth, soil drainage). At the same time, analysis and characterization of specific technology requirements and their functions were given inadequate emphasis. These generally have led to inappropriate technology targeting, which then led to limited effectiveness and efficiency of interventions (Kassie et al., 2010). Furthermore, institutional and governance elements have contributed to low uptake and dissemination of technologies and strategies and need to be considered in the targeting of SLM strategies and technologies.

To make an efficient use of SLM technologies and effective landscape management options, practitioners and planners should have the capacity to understand and analyze the landscape/watershed characteristics so that they can be able to identify and select the required technologies that fit the area under consideration. This can be supported with a framework and tool that can enable identifying critical problem areas, defining suitable management options and matching these two spatially. However, there are no such framework and the existing guideline is generic and coarse to be useful for specific situations and conditions. As a result, mismatch between the conditions/attributes of watersheds and the requirements and functions of technologies was identified as one of the major problems for the 'failure' of watershed management interventions. In addition, there is lack of integrated technology implementation on the topo-sequence such that they are complementary and promote synergy. On the other hand, the various SLM technologies might have multiple functions when applied under different conditions. Whenever the specific technology is not implemented at the right condition, it results in undesirable environmental impact leading to low adoption due to the negative perception by the land users.

A consensus exists that there is a need to improve land conditions through implementation of SLM technologies that are guided by research. SLM comprises measures and practices adapted to biophysical and socio-economic conditions aimed at the protection, conservation and sustainable use of resources (soil, water and vegetation) and the restoration of degraded natural resources and their ecosystem functions. However, for a certain set of biophysical/environmental and socio-economic conditions, the practical challenge is to select and place appropriate/optimum technologies that can fit to site specific context that land users can implement to prevent degradation and restore degraded land. Methods for assessing land degradation, impact assessment and assessing the trade-offs already exist (Kizito et al., 2018; Tamene & Le, 2015). The challenge is these are implemented in an isolated manner and no framework/tool is available to handle the diagnosis-restoration-impact assessment pathway in an integrated manner.

Further, the challenge now is how to develop an integrated framework that can be used in near real-time using current technological capabilities. With increased access to Earth Observation technologies, and the growth in computing power, decision support tools are needed to help countries to monitor the degradation and restoration processes. More importantly, methodologies need to be adapted locally. To achieve effective landscape restoration and accelerate the adoption of restoration technologies, there is a need for technology targeting decision support tools that can match landscape conditions with the appropriate restoration options. An ideal decision support tool/guideline should be able to match landscape conditions with the appropriate technology options (measure) while making sure that landscape conditions will satisfy technology functions and/or requirements. Ultimately, the tool helps to guide practitioners to identify specific technology recommendation domains. Professionals, planners and decision-makers can use the information and products generated from these analyses to identify the most suitable SLM practices and technologies for targeted areas and communities.

The aim of this report is to develop detailed framework that can be used to develop a decision support tool to target land management options across landscapes in an optimal manner and generate evidences of the interventions in terms of ecosystem services. The framework will guide identification of hotpots, allocation of suitable technologies, match these two and generate evidences of the performances of the interventions. Details of the sequential activities are presented in the next section.

APPROACHES

2.1. Conceptual framework

We use the analogy that is normally followed to treat a patient. When a person fills unwell, the normal process in the clinic is to undertake diagnosis in order to define the part of the body that is not well. Once that is done next step will be to study the problem area in greater detail to understand the case of the problem. With this, the physician will prescribe medicine and provide detailed instructions of the prescription of the medicine and the time it has to be taken. When this prescription is made an effort should be made that the medicine will not have side effects on the patient. There will also be follow up to make sure that the medicine is working well and the patient is showing sign of recovery. Once the patient has recovered; proper guidance will be given to him about the care he has to take including food, exercise and the likes with regular dates fixed for check-up. We think that this routine is what should be followed in the case of landscape restoration (Fig. 1). Below we will try to outline the key steps and processes to treat and restore degraded landscapes.

Figure 1: The ‘value chains’ involved in targeting SLM technologies in a landscape: problem identification to optimization of solutions across space and evidence generation

2.2. Diagnosis and characterization

At the 2012 United Nations Conference on Sustainable Development (Rio+20), governments adopted the concept of ‘zero net land degradation’, thereafter Land Degradation Neutrality (LDN) was adopted by the UN General Assembly as part of the Sustainable Development Goals (SDGs), specifically SDG Target 15.3, the concept expressed a desire by governments to prevent further degradation of land by aiming to combat desertification, restore degraded land and soil, including land affected by desertification, drought, and floods, and strive to achieve a land-degradation-neutral world” by 2030 (UNCCD, 2012). The methodology has already been operationalised in several countries (Kapović Solomun et al., 2018; Kiani-Harchegani & Sadeghi, 2020; Nijbroek et al., 2018) and could provide an initial land diagnosis at a pixel level.

Following the conceptual framework work of the LDN, landscape diagnosis options were identified through review of WOCAT technology questionnaire (WOCAT, 2018), the Community based Participatory Watershed Guideline of Ethiopia and other related literatures. A range of agro-climatic, topographic and soil factors that can serve to diagnose landscape condition and identify hotpot areas of intervention were assessed. The major parameters used to diagnose areas of intervention are vegetation condition (NDVI, NPP), land use/cover change and soil carbon stocks (Cowie et al., 2018). In addition to these variables proposed by the LDN framework, soil erosion is included as an important mechanism to diagnose land condition in our study. This is because soil erosion is a very serious problem and land restoration prioritization in the country mainly considers the risk of soil erosion. While identifying major hotpots is essential to prioritize intervention areas, detailed characterization is equally important to identify and suggest relevant management options. For the later, key information will be needed possibly at higher spatial resolution. Table 1 shows the important factors that can be used to identify priority areas of intervention and characterize in terms of potentials and constraints.

Table 1. Landscape factors to characterize site conditions, their relevance and availability

SN	Landscape factors	Relevance	Availability of information	Reliability
1	Agro-ecology	• Relevant to identify landscape functions and broad factor to use for specific technology selection	• Spatial layers for 18 AEZs and traditional classes	• Course scale-medium reliable
2	Rainfall amount	• Relevant to classify recharging, runoff and moisture management conditions (graded & level structures)	• High resolution satellite-based rainfall data	• Reliable if calibrated
3	Land use*	• Type and intensity of land use affects the choice of technologies and practices	• Extract from land cover using expert analysis	• Reliable
4	Landform	• An important factor to determine the land management options and integrated technological options relevant for erosion control, runoff management and water productivity	• Derive from topographic layers	• Reliable
5	Slope gradient	• Slope affects the design, layout and stability of SWC structures	• Easily derived from DEM	• Reliable
6	Slope shape (uniform, concave, convex)	• Relevant to decide hydrologic flux conditions that affects the choice of type of structures either for water harvesting or runoff drainage or recharging. It also guides how the topo-sequence connectivity of structures look like.	• Derive from secondary derivative of slope	• Reliable
7	Soil depth	• Indirectly, soil depth helps to know the initial runoff abstraction and water holding capacity of the soil that affects the structural storage efficiency and spacing	• Available from AfriSIS/ EthioSIS	• Medium reliable
8	Soil drainage/ permeability	• Limits the choice of SWC structures either for moisture conservation or runoff drainage	• No information /use pedo-transfer function	• Low/medium reliability
9	Soil texture	• Affects the water retention and holding capacity and erosion transport rate	• Texture triangle-based water holding scale	• Medium reliable
10	Soil erodibility	• Help to understand rate of erodibility and decide on the design and layout of structures	• Literature by texture type	• Less reliable
11	Land tenure/ Use right	• Help to choose technologies that require secured use right and the need for collective actions or individual management	• Extract from land cover using expert analysis	• Course scale and medium reliable
12	Farm size	• It is important to identify options that fit to the farm size	• CSA/land holding by kebele/district	• Course scale and medium reliable

* Texts with **red** refer socio-economic related landscape factors, which are not considered for the technology targeting at this stage.

2.3. Identifying and characterizing suitable SLM and climate smart practices/technologies

Landscape restoration effort takes time and benefits accrue after long period of investment. Identifying options that can bring multiple benefits (food, feed, soil health, pollination, etc.) and generate income are more attractive and sustainable. Those that empower women and create jobs for the youth are also critical as they target important segments of the society. It is thus essential to consider socio-economic situations when identifying land restoration technologies in addition to biophysical suitability. It is also necessary to pay attention to environmental sustainability make sure that associated tradeoffs are minimum.

In general co-identification of technologies and practices is essential to make sure that the needs and interests of local communities and smallholder farmers are factored in. Local knowledge and experiences are also crucial to consider so that exogenous options that maybe difficult to materialize in the specific situations will not be prioritized by researchers. Once the options are co-identified the next step will be to conduct detailed characterization – in terms of suitability and requirements of the respective technologies. The performances of technologies depend on the environmental suitability of the area where they are implemented and associated management practices in place to sustain those efforts. Knowledge of the requirements of the technologies can enable not only locating them in suitable areas where they can perform but also can enable subscribing appropriate management options. It is thus essential to assess the suitability, appropriateness and adaptation conditions of technologies visa viz characteristics of the locations of implementation.

Effective land restoration can be achieved through sustainable land management planning – the systematic assessment of landscape conditions and its functions – is needed to help land users and practitioners select, put and adapt appropriate SLM technology options (biological/vegetative, agronomic and structural) into practice in a given farm or wider landscape with the aim of maintaining land and water productivity and other ecosystem services. Although there is considerable experience on SLM practices, there have been gaps to provide decision tools to ensure the selection and placement of appropriate and more suitable SLM technologies for a given set of landscape conditions. This is an important step in ensuring the effectiveness of land management and restoration. Common questions are:

(i) What farm/landscape/biophysical factors affect the SLM focus strategies or purposes of SLM practices in general and the functions and adaptation of SLM technologies in particular?
(ii) For a certain set of landscape/biophysical conditions, what specific functions can be enhanced to ensure effective restoration of degraded lands and productivity of landscapes?

Successful land scape restoration can be achieved through the following steps:

1. Setting Strategies/Purposes of SLM Practices

At the broader scale, areas need to be categorized based on SLM focus strategies or purposes depending on the prevailing broader conditions as listed in Table 2. Agro-ecological zones and particularly rainfall regimes help to determine domain of appropriate SLM strategies. Areas which have excess, optimum and deficit rainfall conditions are categorized separately. Accordingly, the following strategies/purposes are identified:

1. Under excess rainfall (humid) conditions, the broader focus strategies include:
    - Excess runoff management strategies.
    - Erosion control and sediment management strategies.

- Land use and cover management strategies like afforestation and mountain development.

2. Under optimum rainfall (sub-humid) conditions, the focus strategies are:
    - Infiltration management using soil management practices.
    - Agronomic management strategies.
3. Under deficit rainfall (Semi-arid and arid) conditions, the focus strategies are:
    - Rainwater management.
    - Soil water storage or moisture conservation.
    - Agronomic strategies.

Table 2. Purposes of SLM strategies and specific landscape functions of SLM practices

Purposes of SLM practices	Functions of SLM technologies	Scale of Application
Increase vegetation cover	Increase intensity of land cover	Farm, Landscape
Increase biomass	Increase vegetation intensity	Farm
Maintain soil fertility and organic matter	Maintain organic matter and nutrients	Farm
	Increase micro-organisms	Farm
Reduce soil acidity	Lower soil pH	Farm
Increase infiltration	Decrease rain drop impact	Farm
	Decrease soil compaction & sealing	Farm
	Increase soil cover	Farm
Soil water storage/moisture conservation	Retention of rain/runoff	Farm, Landscape
	Retain soil moisture	Farm
Runoff management (retain, store and discharge runoff water)	Retard runoff velocity	Farm, Landscape
	Intercept runoff water	Farm, Landscape
	Discharge runoff water	Farm, Landscape
	Recharge sub-surface water	Landscape
	Store rain/runoff water	Farm
Sediment management (control soil erosion and retain sediment)	Reduce loss of top soil/surface erosion	Farm
	Retain eroded sediment	Farm
	Modify/decrease slope gradient	Landscape
Biodiversity conservation	Increase vegetation diversity	Farm
	Reducing invasive species	Farm, Landscape
Buffering capacity	Increase buffering for flooding	Landscape
	Increase buffering for pollution	Farm, Landscape
Increase quantity of surface and ground water	Recharging	Landscape
	Intercept runoff	Farm, Landscape
	Store rain and runoff-water	Farm

2. Identification of SLM Functions based on Specific Landscape Conditions

Given the broader strategies of SLM under different agro-ecological areas, further classification of areas/landscapes based on other topographic, soil and land use factors can help to identify site and context specific water/hydrologic, soil and vegetation functions.

3. Characterization of SLM Technologies: Functions and Requirements

The main agricultural land use types considered in this assignment are crop land, grazing land and degraded lands. Specific land conservation measures are practiced to crop land, grazing land and degraded communal lands, and sometimes on mixed land uses like grazing and degraded lands. Different land degradation problems occur depending on the type of land use. The common land use problems occurring on crop lands include soil erosion in the form of sheet erosion and rill erosion, soil erosion by gullies, conversion of other land uses to cultivated lands, steep slope cultivation and land fragmentation, shallow soil depth and nutrient depletion, excessive removal of crop residues, excessive and inappropriate construction of farm runoff drainage ditches, and low productivity of crops. Problems that occurred on grazing/pasture lands are constituted from shortage of pasture lands, overgrazing, free grazing, soil degradation, and water scarcity. Degraded communal lands have experienced severe soil degradation, loss of vegetation, and water scarcity. Shortage of fuel wood, shortage of land, and increased demand of trees for the purpose of fuel wood and timber were the characteristic problems of landscapes across to all land use types.

Such contextual land use and land management changes have resulted in unintended environmental consequences which potentially undermine future land use options and degrade ecosystem services. Maintaining ecosystem functioning/services is a prerequisite for sustainable land management (SLM). SLM harbors great potential for preservation and enhancement of ecosystem services in all land use systems. Degradation of water, soil and vegetation can be limited by SLM practices that simultaneously conserve natural resources and increase yields.

The process of SLM planning to select and place management measures at specific sites should be guided by understanding the concept and principles of SLM practices. The concept and definition of SLM practices can be narrated as follows.

(i) According to UNCCD: Practices in SLM are defined as: "Measures, methods or activities; that perform best or achieve the highest impact according to pre-defined criteria assessed through a validation process."

(ii) "SLM practices are practices that increase production and are profitable, cost-efficient with primarily rapid, but also long-term payback, are easy to learn, socially and culturally accepted, effectively adopted and taken up, environmentally friendly and are appropriate for all stakeholders including socially marginalized groups" (Liniger, H. et al., 2011).

(iii) According to WOCAT database, “an SLM technology is a physical practice on the land that controls land degradation, and enhances productivity and/or other ecosystem services.” (https://www.wocat.net/en)

According to Liniger, H. et al. (2011), the principles for SLM technologies/practices towards the objectives of increased land productivity, improved livelihoods and ecosystems are described as follows.

(i) Improving water productivity through reducing water loss, harvesting water, maximizing water storage and managing excess water;
(ii) Improving soil fertility by reducing leaching, erosion, mining of soil fertility, and improved management of soil organic matter;
(iii) Improving ecosystems and being environmentally friendly through reducing land degradation, resilient to climate change and improving biodiversity;
(iv) Improving livelihoods through the provision of short term and long-term benefits, in terms of higher net returns and cost efficiency, and participation and land use planning.

Moreover, according to the SLM source book of The World Bank (Franzel et al., 2008), for rain fed systems good land management requires an integrated and synergistic resource management approach that embraces locally appropriate combinations of technical options as a set of principles. The detailed technical options as principles of SLM practices include:

(i) Build-up of soil organic matter and related biological activities for improved moisture storage, nutrient supply, and soil structure;
(ii) Integrated plant nutrition management with locally appropriate and cost-effective combinations of organic or inorganic and on-farm or off-farm sources of plant nutrients;
(iii) Better crop management using improved seeds and agronomic practices;
(iv) Better rainwater management to increase infiltration and reduce runoff;
(v) Improvement of soil rooting depth and permeability;
(vi) Rehabilitation, if technically feasible and cost-effective, of cultivated land that has been severely degraded by such processes as gullying, loss of topsoil from sheet erosion, soil compaction, or acidification.

These principles are used as a basis for identification and selection of SLM technologies. Considering these concepts and principles, the SLM measures need to be environmentally friendly, socially accepted, profitable and cost-efficient and achieve highest impact on productivity and other ecosystem services. To meet these criteria, detail characterization of the functions and requirements of SLM technologies/ measures is essential and help to guide practitioners and planners where to place them.

Based on WOCAT classification, SLM technology options can be vegetative, mechanical/structural and agronomic measures. The specific technologies in each category which are commonly implemented and adapted in the Ethiopian context are identified from the info-techs in the Community Based

Participatory Watershed Development Guideline. Although the info-techs listed several categories of SLM technologies, we considered only the physical/mechanical soil conservation measures for the time which are appropriate for the specific assignment. The commonly applied physical technologies such as bench terrace, soil bund, fanya juu, stone bund/stone-faced soil bund, hill side terrace, trenches, etc. are considered. These technologies are characterized based on the functions and their landscape requirements. In principle, at certain landscape conditions, the specific technology options have provided specific functions to prevent, control and manage the soil, water and vegetation resources. The functions include:

- Land use change to prevent and mitigate land degradation and restore degraded lands;
- Improve vegetation cover;
- Manage soil organic matter and soil fertility;
- Control runoff velocity and safely discharge excess runoff;
- Control soil erosion and manage sediment transport;
- Improve soil-water storage and infiltration;
- Recharge sub-surface water;
- Promote rainwater and runoff harvesting.

In addition, by considering these functions of the technology options, the agro-climate, topographic, soil and land use requirements needed to achieve these functions are described in Table 3.

Table 3. Description of SLM technologies

SN	SWC technology	Description	Functions	Limiting/constraining factors
1	Grass strips	Consist of grass planted in strips along the contour lines and spaced at suitable intervals. It addresses surface erosion by water.	Retard runoff velocity Retain eroded sediment	Low rainfall/moisture stress Grazing management/free grazing
2	Agronomic conservation measures	Agronomic techniques are practice of combination of crop residue, mulching, intercropping and strip-cropping in a suitable farming system and environmental conditions. It solves chemical and physical soil degradation and soil moisture stress.	Increase infiltration and thereby reducing surface runoff and soil erosion Reduce impact of raindrops through interception	Low cropping intensity/cover and steep slopes Competitive use of crop residues for feed and fuelwood
3	Contour ploughing	Soil is ploughed along the contour instead of up- and downward and used to reduce surface erosion.	Retard velocity of runoff and thus soil erosion by concentrating water in the downward furrows Retain soil moisture	High rainfall Shallow soil depth
4	Bench terrace	A series of level or nearly level strips built along the contour lines at suitable intervals supported by steep banks or risers. It controls soil erosion by water.	Modify slope gradient by reducing the degree and length of the slope and control erosion and retain sediment Increase infiltration of rain water	Shallow soils Non-workable soils
5	Stone walls	It the use of rocks and stones lying on the slope and build low stone walls to control soil erosion by water.	Control soil erosion and runoff velocity Reduce slope length	Unavailability of stones Steep slope
6	Hillside terrace	A hillside terrace is a physical barrier constructed on hills to conserve soil moisture. It is a structure along the contour where a strip of land, about 1 meter wide, is levelled for tree planting. It controls soil erosion and enhance soil moisture.	Retard runoff velocity and intercept runoff Retain eroded sediment	Poor soil drainage
7	Semi-circular bunds	It involves building low embankments with compacted earth or stones in the form of a semi-circle with the opening perpendicular to the flow of water. It addresses soil moisture stress.	Intercept rain and runoff for crop, tree or grazing	Poor drainage and steep slope
8	Fanya Juu	Fanya juu terraces comprise embankments (bunds), which are constructed by digging ditches and heaping the soil on the upper sides to form the bunds. Constructed on the contour to hold rainfall where it falls. It addresses soil erosion by water.	Retard velocity of runoff and drain safely Retain eroded sediment	Steep slope High intensity of rainfall
9	Level soil bund	Impermeable structures constructed along the contour and across the slope. It controls soil erosion by water and improve soil moisture	Reduce velocity of runoff Retain eroded soil and conserve soil moisture	Poor drainage High rainfall
10	Stone bunds	Stone bunds increase the moisture retention capacity of the soil profile and water availability to plants, and increase the efficiency of fertilizer applications. It controls soil erosion by water and improve soil moisture	Reduce velocity of runoff Reduce soil erosion and retain sediments	Poor soil drainage and very steep slopes Unavailability of stones
11	Stone faced soil bunds	Stone faced soil bunds are applicable where need to reinforce one or both sides of the embankment with a stone wall or riser. It controls soil erosion by water and improve soil moisture.	Stone bund reduces the velocity of runoff Reduce soil erosion and retain sediments	Poor soil drainage
12	Hillside ditches	A series of shallow ditches built along the contour lines at appropriate intervals. It controls soil erosion by water and improve soil moisture.	Intercept and store surface runoff and recharge sub-surface water	Poor soil drainage
13	Trenches	Trenches are shallow to deep pits constructed along the contours. It controls soil erosion by water and improve soil moisture and sub-surface flow	Collect and store rain water to support the growth of trees, shrubs, cash crops and grass Recharge springs, wells and groundwater	High rainfall and rocky soils Poor soil drainage
14	Micro-basins	Micro-basins are small circular and stone faced (occasionally sodded) structures for tree planting. It controls soil erosion by water and improve soil moisture and sub-surface flow	Collect rain & runoff and conserve soil moisture Recharge springs, wells and groundwater	High rainfall and rocky soils Poor drainage
15	Tie-ridging	Tie ridges are small rectangular series of basins formed within the furrow of cultivated fields. The principle or purpose is to increase surface storage by first making ridges and furrows, then damming the furrows with small mounds, or ties. It addresses soil moisture stress.	Increase soil moisture storage Increase infiltration	Rainfall variability Poor soil drainage

Through the above steps planners, practitioners and land users can make decisions on what appropriate technologies to select for site specific context and where to place them in a certain landscape.

2.4. Matching options with context – restoration scenarios and on the ground implementation

The previous steps discuss landscape factors affecting technology selection, site specific set of water, soil and vegetation functions prevailing at different landscape conditions on the one hand and the requirements of SLM technologies on the other. Thus, the selection of SLM technologies can be achieved by matching site-specific functions identified in step 2 to the technology functions and requirements identified in step 3. Once the technologies are identified and selected for a specific landscape context, a more fine-tuned placement of SLM technologies can be undertaken at specific levels or classes of the landscape factors (rainfall, slope gradient, landform, slope shape, permeability, soil depth, etc.).

Generally, it is important to implement linked technologies that can complement each other and generate multiple benefits for multiple users at multiple scales. The technologies can be placed following the landscape continuum (Fig. 2). Since restoration is not intended to fix a single problem at a given spot, it is necessary that technologies be placed across the landscape continuum (Fig. 2). Though local variations are expected due to variability in landscape attributes (including land use/cover types) and the associated requirements of land and water management technologies, the general tendency is that a mosaic complementary and linked technologies are placed across the landscape. Afforestation/reforestation are common practices on the upper part of the landscape baring than competing uses do not exist. Soil and water conservation structures occur at the upper landscape; water harvesting schemes at the middle and lower landscape, and different soil improvement and water storage technologies within the respective farmlands. These options can be co-located and/or staggered across space considering complementary. Soil and water conservation measures are generally completed with biological options with multiple benefits to retard soil erosion, enhance soil moisture, improve soil health, and provide fodder for livestock. In addition, fruit/vegetable crops can be integral components mainly associated with homesteads and water harvesting sites.

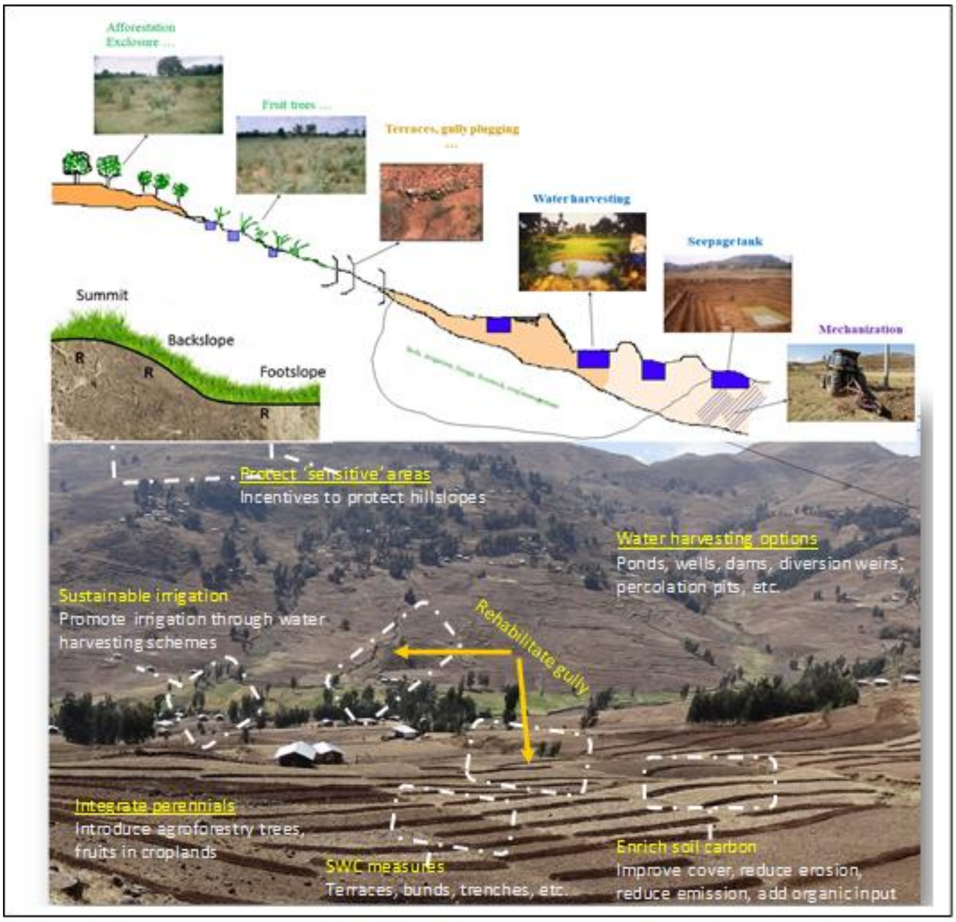

Figure 2: Land and water management technologies that can be implemented across the landscape continuum to address different problems and maintain complementarity

2.5. Evidence generation

Ethiopia is engaged in huge landscape restoration undertakings. The Government of the country is committed to complete restoration of 22 million ha of degraded forests, woodlands and agricultural landscapes in the coming ten years. The sustainable land management program (SLMP) has been engaged in intensive restoration effort covering large part of the country. The government and its partners are committed this engaged until the problem of land degradation is tackled and degraded landscapes restored. Despite these widespread efforts and commitment by the government and its partners, there is generally a lack of quantitative evidence about the performances of the various interventions to improving livelihoods and enhancing ecosystem services across scales. The results of the few studies are also inconsistent, non-comprehensive, are based on limited spatio-temporal analysis and most assessments are at plot levels. Moreover, most of the studies followed a sectorial approach where 'achievements' have been evaluated from a perspective of a single 'parameter' such as reduction in soil erosion, gain in soil moisture, improvement in soil fertility, vegetation cover, and the likes. There are also no studies that considered different agro-ecological zones and biophysical conditions alongside socio-economic and cultural domains. Our knowledge about what works where and how, and the risks to scaling up landscape rehabilitation and forest management practices and mechanisms to mitigating those risks thus remain limited. It is thus not possible to understand with evidence the return on investment (ROI) made towards restoring degraded landscapes and sustainably managing natural resources in the country.

Against this background, there is a need to systematically study and document the strengths and limitations of these national efforts so that the country could build on the strengths and address weaknesses in designing and implementing landscape rehabilitation initiatives at scale. Such knowledge and information not only facilitate informed decision-making but also boosts the country's capability to justify its investment and negotiate with carbon and ecosystem services payment schemes at national, regional and global levels.

With advances in earth observation technologies and analytical methods, evidences of restoration efforts have been undertaken covering larger geographical area using before and after satellite images (Giuliani et al., 2020; Liu et al., 2019; Meroni et al., 2017) and/or with and without approaches. Since lack of adequate baseline data has been a problem in the majority of previous restoration efforts it will be essential to make sure that appropriate controls are used to compare with intervention areas. A process can also be established to generate evidence in real-time and provide up to date information for planning and decision making.

2.6. Trade-off analysis and optimization

The ultimate aim of land restoration effort is to generate diverse ecosystem services in a sustainable manner. To achieve this, optimal land use and effective management practices should be in place. Assessing whether the goals have been achieved in a timely manner is essential to make informed decision through adaptive learning. Evidence generation efforts can enable achieving that. In addition, it will be useful to determine the optimum combination of technologies/practices that can provide optimum benefits with limited trade-offs.

Landscapes may not necessarily be bounded by hydrological or biophysical units. Rather, they can be extended beyond watershed boundaries as they encompass land users and social groups outside of a given hydrological zone. This means that the probability of the existence of various land uses and users will be high. In areas where different interest groups with a variety of land use preferences existing the kind of management options can also vary. In addition, the landscape can include upslope-downslope configurations with different needs and priorities. At the landscape scale institutes and stakeholders who are set to manage water, land and forest can have their own competing interests (Fig. 3). Even within a given farm, there can be competing needs in terms of crop, livestock and fodder management (Fig. 3).

Then there is interaction of processes between the different scales that can influence processes at the other scale. There is thus a need to consider and account for competing uses and users of resources when planning landscape restoration. This means bringing various stakeholders together to discuss priorities, needs, preferences and develop working modalities. Detailed trade-off analysis between overall production-conservation goals and competing needs and uses within each will be essential. This can enable identifying and implementing land and water management interventions that consider the landscape configuration, potentials, upslope-downslope interactions, and that provide multiple benefits to enhance both productivity and resilience of landscapes and communities. Such approach that also enable to promote sectoral/institutional integration and implement complementary options across the landscape continuum to enhance both ecological, economic and socio-cultural benefits and ultimately sustain peoples' livelihoods and economic growth in a sustainable manner.

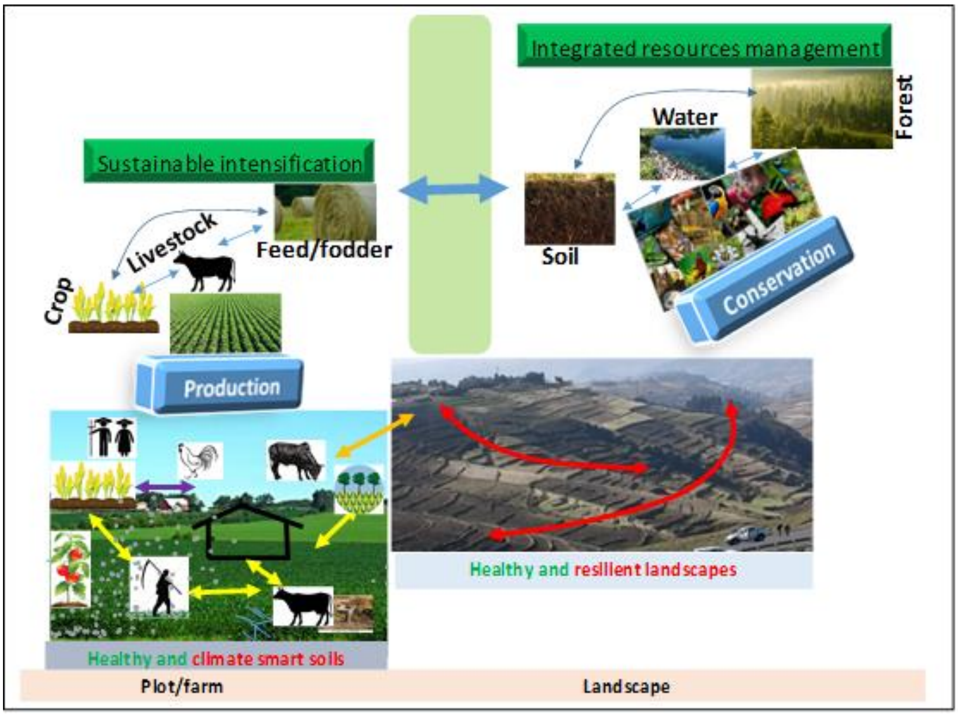

Figure 3: Figure 3. Interactions and feedbacks between different uses and users of land across scale

At this stage, the trade-offs between economic gains and ecological losses of land restoration options at various temporal and spatial scales need to be quantified.

TESTING AND VALIDATING THE FRAMEWORK

The framework will be tested through highly experienced expert views and field survey. About 5-7 senior experts who have long experience in the areas of soil and water conservation and watershed management will be involved in the testing of the tool. The field test will be carried out at different contexts where we find different agro-climatic, topographic and soil conditions. Later, validation of the decision tool will be undertaken at selected project watersheds such as SLMP, MERET, PSNP, WLRC, and Africa RISING.

GUIDING PROCEDURES FOR APPLYING THE FRAMEWORK

1. Purpose of the framework

This framework is mainly targeted to select and place physical practices of SLM and does not help to guide the identification of agricultural intensification options as it requires to assess more farming system and agricultural production factors. This framework can specifically be used to guide the development agents, experts and watershed planners with good knowledge of the landscape/watershed contexts/conditions and enable them to identify, select and place SLM physical technology options. On the other hand, although it is not preferable, it can be used to guide the development agents, experts and watershed planners with good knowledge of the SLM physical technology options and enable them to identify the landscape/watershed areas where to place/implement the technology.

2. Preconditions

The framework can be used most effectively when the users have a good knowledge of their local context, at least the agro-climate, topographic and soil conditions and socio-economic contexts that mainly influence the suitability and adoption of SLM technologies. In addition, the application of this tool is more enhanced when it is complemented with knowledge of geospatial layers to identify landscape factors. For this purpose, it is recommended to access and use EthioGIS II and Watershed Tool developed by WLRC or other similar open access geospatial tools that provide high resolution functionality.

3. Decision making process

The decision making through the four steps discussed above follows a hierarchical analysis. First, a complete landscape diagnosis is carried out to pin-point degraded areas using tested methodologies e.g. LDN, land restoration entails (i) using agro-ecology and/or rainfall factors to identify broader domains of SLM strategies, (ii) using landscape factors such as topographic (slope gradient, land forms, and slope shape) and soil factors (soil depth, soil drainage) to identify the landscape management functions in water, soil and vegetation aspects and then matching with the appropriate SLM technology options, (iii) placing appropriate SLM technology options to the detail levels or classes of landscape factors so that users enable to place the options on the operating landscapes. Then, evidence of restoration process is generated by quantifying the effects of land restoration efforts. Finally, the trade-offs between economic gains and ecological losses of land restoration options at various temporal and spatial scales are quantified.

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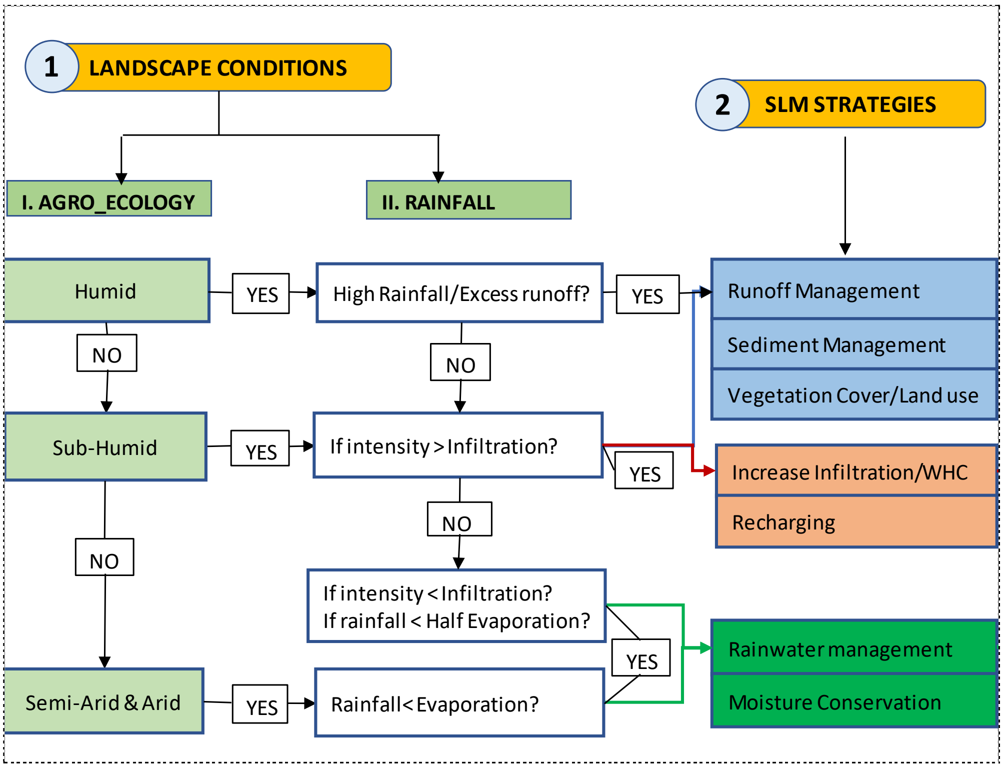
APPENDIX 1: THE SLM TECHNOLOGY TARGETING DECISION TOOL/FRAMEWORK



1 LANDSCAPE CONDITIONS

3 LANDSCAPE FUNCTIONS

4 SELECTION of SLM TECHNOLOGIES

II. RAINFALL	III. SLOPE GRADIENT	IV. LAND FORM	V. PERMEABILITY	Land use & Vegetation Management: Change land use	Land use & Vegetation Management: Increase soil cover	Runoff management & erosion control: Modify slope	Runoff management & erosion control: Drain runoff	Runoff management & erosion control: Control runoff velocity	Runoff management & erosion control: Recharge	Infiltration management: Increase WHC/OM	Infiltration management: Increase infiltration	Infiltration management: Intercept rain/runoff	Rainwater & moisture conservation: Store rain /runoff	Rainwater & moisture conservation: Retain moisture
High Rainfall (>1000 mm)	Steep Slope (>30%)	Ridges & Hills	Slow (<0.5cm/hr)	+++	+++	++	+++	+			+++			
			Moderate (0.5-12.7 cm/hr)	++	+++	++	++	+		+	++			
			Rapid (>12.7 cm/hr)	+++	++	+++			++	+++		+++		
	Moderate slope (16-30%)	Hills	Slow	+	+++	+	+++	+			+++			
			Moderate		++	+	+	++	+	+	++			
			Rapid		++	++			+++	++		+++		
		Foot slopes	Slow		++		++				++		++	
			Moderate		+		+	++	++	+	+		+	
			Rapid		+				+++	++		+++		
	Lower slope (<15%)	Plateau /Plain	Slow		+++		++				+++		+++	
			Moderate		++		+	+	++		+		++	
			Rapid		+++				+++	+++		++		
		Valley	Slow		+++		++				+++		+++	
			Moderate		++		+	+	++		+	+	+	
			Rapid		+++				+++	+++		++		
Medium Rainfall (750-1000 mm)	Steep Slope (>30%)	Ridges & Hills	Slow	+++	+++	++	++				++			
			Moderate	++	+++	++	+	+	+	+	+	+		
			Rapid	+++	++	+++			++	+++		++		
	Moderate slope (16-30%)	Hills	Slow	+	+++	+	++	+			+++			
			Moderate		++	+	+	+	++	+	++	+		
			Rapid		++	++			+++	++		++		
		Foot slopes	Slow		++		+	+			++		+++	
			Moderate		+		+	+	++	+	+	+	++	
			Rapid		+				+++	++		+++		
	Lower slope (<15%)	Plateau /Plain	Slow		+++		+				++		+++	
			Moderate		++			+	+		+	+	++	
			Rapid		+++				++	+++		+		
		Valley	Slow		+++		+				++		+++	
			Moderate		++			+	++		+	+	++	
			Rapid		+++				+++	+++		++		
Low Rainfall (<750 mm)	Steep Slope (>30%)	Ridges & Hills	Slow	+++	+++	++					+		+	
			Moderate	++	+++	++				++		++	++	++
			Rapid	+++	++	+++				+++		+++		+++
	Moderate slope (16-30%)	Hills	Slow	+	+++	+				+		+	++	+
			Moderate		+++	+				++		++	+++	++
			Rapid		++	++				+++		+++		+++
		Foot slopes	Slow		+++					+		+	+++	+
			Moderate		+++					++		++	++	++
			Rapid		++					+++		+++		+++
	Lower slope (<15%)	Plateau /Plain	Slow		+++							+	+++	++
			Moderate		++					++		++	++	+++
			Rapid		+++					+++		+++		+++
		Valley	Slow		+++							+	+++	++
			Moderate		++					++		++	++	+++
			Rapid		+++					+++		+++		+++

II. RAINFALL	III. SLOPE GRADIENT	IV. LAND FORM	V. PERMEABILITY	Vegetative SLM measures	Mechanical SLM measures	Soil mang't and soil water storage SLM measures	VI. SOIL DEPTH: Shallow (<50cm)	VI. SOIL DEPTH: Moderate (50-80cm)	VI. SOIL DEPTH: Deep (>80cm)	VII. SLOPE SHAPE: Concave	VII. SLOPE SHAPE: Uniform	VII. SLOPE SHAPE: Convex
High Rainfall (>1000 mm)	Steep Slope (>30%)	Ridges & Hills	Slow (<0.5cm/hr)	AFF	WW							
			Moderate (0.5-12.7 cm/hr)	AFF	BT,HT GSTB GSFSB WW		HT/STB/SFSB	BT/STB/SFSB	BT/STB/SFSB	STB/SFSB	BT/HT/STB/SFSB	BT/HT/STB/SFSB
			Rapid (>12.7 cm/hr)	AFF	BT,HT GSTB GSFSB		HT/STB/SFSB	BT/STB/SFSB	BT/STB/SFSB	STB/SFSB	BT/HT/STB/SFSB	BT/HT/STB/SFSB
	Moderate slope (16-30%)	Hills	Slow	AF AC	WW							
			Moderate	AF AC	SW,HT GSB GSTB GSFSB WW	TR	HT/SW/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SB/STB/SFSB/TR	SW/SB/STB/SFSB	SW/HT/SB/STB/SFSB/TR	HT/STB/SFSB
			Rapid	AF AC	SW,HT GSB GSTB GSFSB	TR	HT/SW/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SB/STB/SFSB/TR	SW/SB/STB/SFSB	SW/HT/SB/STB/SFSB/TR	HT/STB/SFSB
		Foot slopes	Slow			WHP						
			Moderate		SW GSB GSTB GSFSB WW	TR	SW/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SW/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SW/SB/STB/SFSB/TR	STB/SFSB
			Rapid		SW GSB GSTB GSFSB WW	TR	SW/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SW/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SW/SB/STB/SFSB/TR	STB/SFSB
	Lower slope (<15%)	Plateau /Plain	Slow		BBF	WHP						
			Moderate		SW GFJ, GSB GSTB GSFSB WW	WHP	SW/STB/SFSB	SW/FJ/SB/STB/SFSB	FJ/SB/STB/SFSB	SW/FJ/SB/STB/SFSB	SW/FJ/SB/STB/SFSB	STB/SFSB
			Rapid		SW LFJ, LSB LSTB LSFSB WW		SW/STB/SFSB	SW/FJ/SB/STB/SFSB	FJ/SB/STB/SFSB	SW/FJ/SB/STB/SFSB	SW/FJ/SB/STB/SFSB	STB/SFSB
		Valley	Slow		BBF	WHP						
			Moderate		GFJ, GSB GSTB GSFSB WW	TR WHP	STB/SFSB/TR	FJ/SB/STB/SFSB/TR	FJ/SB/STB/SFSB/TR	SW/FJ/SB/STB/SFSB/TR	SW/FJ/SB/STB/SFSB/TR	STB/SFSB
			Rapid		LFJ, LSB LSTB LSFSB WW	TR	STB/SFSB/TR	FJ/SB/STB/SFSB/TR	FJ/SB/STB/SFSB/TR	SW/FJ/SB/STB/SFSB/TR	SW/FJ/SB/STB/SFSB/TR	STB/SFSB
Medium Rainfall (750-1000 mm)	Steep Slope (>30%)	Ridges & Hills	Slow	AFF	WW							
			Moderate	AFF	BT,HT GSTB GSFSB WW	TR	HT/STB/SFSB/TR	BT/STB/SFSB/TR	BT/STB/SFSB/TR	STB/SFSB	BT/HT/STB/SFSB/TR	BT/HT/STB/SFSB
			Rapid	AFF	BT,HT GSTB GSFSB	TR	HT/STB/SFSB/TR	BT/STB/SFSB/TR	BT/STB/SFSB/TR	STB/SFSB	BT/HT/STB/SFSB/TR	BT/HT/STB/SFSB
	Moderate slope (16-30%)	Hills	Slow	AF AC	WW							
			Moderate	AF AC	SW,HT GSB GSTB GSFSB WW	TR	SW/HT/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SB/STB/SFSB/TR	SW/HT/SB/STB/SFSB	SW/HT/SB/STB/SFSB/TR	HT/STB/SFSB
			Rapid	AF AC	SW,HT GSB LSTB LSFSB	TR MB	SW/HT/STB/SFSB/TR	SW/SB/STB/SFSB/TR	SB/STB/SFSB/TR	SW/HT/SB/STB/SFSB	SW/HT/SB/STB/SFSB/TR	HT/STB/SFSB
		Foot slopes	Slow		WW	WHP						
			Moderate		SW GFJ, GSB GSTB GSFSB WW	TR MB WHP	SW/STB/SFSB/TR/MB	SW/FJ/SB/STB/SFSB/TR/MB	FJ/SB/STB/SFSB/TR/MB	SW/FJ/SB/STB/SFSB/TR/MB	SW/FJ/SB/STB/SFSB/TR/MB	STB/SFSB
			Rapid		SW LFJ, LSB LSTB LSFSB	TR MB	SW/STB/SFSB/TR/MB	SW/FJ/SB/STB/SFSB/TR/MB	FJ/SB/STB/SFSB/TR/MB	SW/FJ/SB/STB/SFSB/TR/MB	SW/FJ/SB/STB/SFSB/TR/MB	STB/SFSB
	Lower slope (<15%)	Plateau /Plain	Slow		BBF	WHP						
			Moderate		SW GFJ,GSB LSTB LSFSB	MB WHP TRG	SW/STB/SFSB/MB	SW/FJ/SB/STB/SFSB/MB/TRG	FJ/SB/STB/SFSB/MB/TRG	SW/FJ/SB/STB/SFSB/MB/TRG	SW/FJ/SB/STB/SFSB/MB/TRG	STB/SFSB
			Rapid		SW LFJ,LSB LSTB LSFSB	MB TRG	SW/STB/SFSB/MB	SW/FJ/SB/STB/SFSB/MB/TRG	FJ/SB/STB/SFSB/MB/TRG	SW/FJ/SB/STB/SFSB/MB/TRG	SW/FJ/SB/STB/SFSB/MB/TRG	STB/SFSB
		Valley	Slow		BBF	WHP						
			Moderate		GFJ,GSB LSTB LSFSB	TR MB WHP TRG	STB/SFSB/TR/MB	FJ/SB/STB/SFSB/TR/MB/TRG	FJ/SB/STB/SFSB/TR/MB/TRG	FJ/SB/STB/SFSB/MB/TRG	FJ/SB/STB/SFSB/MB/TRG	STB/SFSB
			Rapid		LFJ,LSB LSTB LSFSB	TR MB TRG	STB/SFSB/TR/MB	FJ/SB/STB/SFSB/TR/MB/TRG	FJ/SB/STB/SFSB/TR/MB/TRG	FJ/SB/STB/SFSB/MB/TRG	FJ/SB/STB/SFSB/MB/TRG	STB/SFSB
Low Rainfall (<750 mm)	Steep Slope (>30%)	Ridges & Hills	Slow	AFF		WHP						
			Moderate	AFF	BT, HT LSTB LSFSB	TR MB WHP	HT/STB/SFSB/TR/MB	BT/STB/SFSB/TR/MB	BT/STB/SFSB/TR/MB	BT/STB/SFSB	BT/HT/STB/SFSB/TR/MB	BT/HT/STB/SFSB
			Rapid	AFF	BT, HT LSTB LSFSB	TR MB	HT/STB/SFSB/TR/MB	BT/STB/SFSB/TR/MB	BT/STB/SFSB/TR/MB	BT/STB/SFSB	BT/HT/STB/SFSB/TR/MB	BT/HT/STB/SFSB
	Moderate slope (16-30%)	Hills	Slow	AF AC		WHP						
			Moderate	AF AC	SW,HT LSB LSTB LSFSB	TR MB CP WHP	SW/HT/STB/SFSB/TR/MB	SW/CP/SB/STB/SFSB/TR/MB	CP/SB/STB/SFSB/TR/MB	SW/HT/SB/CP/STB/SFSB	SW/HT/SB/CP/STB/SFSB/TR/MB	HT/STB/SFSB
			Rapid	AF AC	SW, HT LSB LSTB LSFSB	TR MB CP	SW/HT/STB/SFSB/TR/MB	SW/CP/SB/STB/SFSB/TR/MB	CP/SB/STB/SFSB/TR/MB	SW/HT/SB/CP/STB/SFSB	SW/HT/SB/CP/STB/SFSB/TR/MB	HT/STB/SFSB
		Foot slopes	Slow			WHP						
			Moderate		SW LFJ,LSB LSTB LSFSB	TR MB CP WHP TRG	SW/STB/SFSB/TR/MB	SW/CP/FJ/SB/STB/SFSB/TR/MB/TRG	CP/FJ/SB/STB/SFSB/TR/MB/TRG	SW/SB/CP/STB/SFSB/TR/MB/TRG	SW/SB/CP/STB/SFSB/TR/MB/TRG	STB/SFSB
			Rapid		SW LFJ,LSB LSTB LSFSB	TR MB CP TRG	SW/STB/SFSB/TR/MB	SW/CP/FJ/SB/STB/SFSB/TR/MB/TRG	CP/FJ/SB/STB/SFSB/TR/MB/TRG	SW/SB/CP/STB/SFSB/TR/MB/TRG	SW/SB/CP/STB/SFSB/TR/MB/TRG	STB/SFSB
	Lower slope (<15%)	Plateau /Plain	Slow			WHP						
			Moderate		SW LFJ,LSB LSFSB	TR MB SCB,CP WHP TRG	SW/SCB/SFSB/TR/MB	SW/SCB/CP/FJ/SB/SFSB/TR/MB/TRG	CP/SCB/FJ/SB/SFSB/TR/MB/TRG	SW/SCB/CP/SB/SFSB/TR/MB/TRG	SW/SCB/CP/SB/SFSB/TR/MB/TRG	SFSB
			Rapid		SW LFJ,LSB LSFSB	TR MB CP TRG	SW/SFSB/TR/MB	SW/CP/FJ/SB/SFSB/TR/MB/TRG	CP/FJ/SB/SFSB/TR/MB/TRG	SW/CP/SB/SFSB/TR/MB/TRG	SW/CP/SB/SFSB/TR/MB/TRG	SFSB
		Valley	Slow			WHP						
			Moderate		LFJ,LSB LSFSB	TR MB SCB,CP WHP TRG	SCB/SFSB/TR/MB	SCB/CP/FJ/SB/SFSB/TR/MB/TRG	CP/SCB/FJ/SB/SFSB/TR/MB/TRG	SCB/CP/SB/SFSB/TR/MB/TRG	SCB/CP/SB/SFSB/TR/MB/TRG	SFSB
			Rapid		LFJ,LSB LSFSB	TR MB CP TRG	SFSB/TR/MB	CP/FJ/SB/SFSB/TR/MB/TRG	CP/FJ/SB/SFSB/TR/MB/TRG	CP/SB/SFSB/TR/MB/TRG	CP/SB/SFSB/TR/MB/TRG	SFSB

LEGEND

- AFF=Afforestation
- AF=Agro-forestry
- AC=Area Closure
- BT=Bench Terrace
- HT=Hillside Terrace
- SW=Stone Wall
- SCB=Semi-Circular Bund
- CP=Contour Plough
- TR=Trench
- MB=Micro-basin
- TRG=Tie-Ridge
- BBF=Broadbed Furrow
- WW=Water Way
- WHP=Water Harvesting Pond
- LSB=Level Soil Bund
- GSB=Graded Soil Bund
- LFJ=Level Fanya Juu
- GFJ=Graded Fanya Juu
- LSTB=Level Stone Bund
- GSTB=Graded Stone Bund
- LSFSB=Level Stone Faced Soil Bund
- GSFSB=Graded Stone Faced Soil Bund

LSTB LSFSB	Marginal Conditions
LSTB LSFSB	

4 PLACEMENT of SLM TECHNOLOGIES		Ranfall (mm)									Slope gradient (%)							Slope shape			Land Forms						Soil Depth (cm)					Permeability (cm/hr)							Soil texture		
SLM Practices	Experts	< 250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-3000	3001-4000	> 4000	Flat (0-2)	Gentle (3-5)	Moderate (6-10)	Rolling (11-15)	Hilly (16-30)	Steep (31-60)	Very steep (> 60)	Concave	Uniform	Convex	Plain/Flat	Ridge	Mountain slope	Hill slope	Foot slope	Valley	Very shallow (0-20)	Shallow (21-50)	Moderate deep (51-80)	Deep (81-120)	Very deep (> 120)	Very slow (<0.13 cm/hr)	Slow (0.13-0.5 cm/hr)	Moderate slow (0.5-2.0 cm/hr)	Moderate (2.0-6.3 cm/hr)	Moderate rapid (6.3-12.7 cm/hr)	Rapid (12.7-25 cm/hr)	Very rapid (>25 cm/hr)	Course/light (sandy)	Medium (loamy, silty)	Fine/heavy (clay)
Bench terrace	Gizaw Desta																																								
Bench terrace	Belayneh Adugna			X	X	X	X	X								X	X						x	x					x	x	x					X	X	X	X	X	
Bench terrace	WOCAT: Alexandra/Konso			X									X	X	X									x			X	X							X				X	X	
Stone walls	Gizaw Desta																																								
Stone walls	Belayneh Adugna			X	X	X						X	X	X	X	X								x			x	x								X	X	X	X	X	
Terrace of DireDawa	WOCAT: Daniel Danano/Dire dawa			X								X	X	X	X							x		x		X		x	x							X			X	X	
Hillside terrace	Gizaw Desta																																								
Hillside terrace	Belayneh Adugna	X	X	X	X	X										X							x	x			x	x							X	X					
Hillside terrace	WOCAT: Hans/Harer/Shewa/Wollo/Tigray/Gonder/Sidamo			X	X											X							x	x			x	x											x	x	
Semi-circular bunds	Gizaw Desta																																								
Semi-circular bunds	Belayneh Adugna	X	X	X								X	X	X							x			x	x	x		x	x						X	X	X		X	X	
Semi-circular bunds	WOCAT: Eyasu Yazew/Kilte Awulalo		X	X									X	X										x	x			x	x					X	X				X	X	
Fanya Juu	Gizaw Desta																																								
fanya juu	Belayneh Adugna			X	X							X	X	X	X								X	x					x	x	x				X	X				X	X
Vegetated fanya juu	WOCAT: Unknown/Kembata				X	X							X	X	X							X	X	x		x			x											X	X
Level soil bund	Gizaw Desta																																								
Level soil bund	Belayneh Adugna		X	X	X							X	X	X	X						x				x	x			x	x					X	X	X		X	X	
Soil bund	WOCAT: Unknown/Hadiya-Lemo				X	X							X	X	X						x	X		x					x	x						X				X	X
Soil bund+fanya Juu	WOCAT: Daniel Danano/Oromia				X						X		X	X										x		x		X	x	x						X					
Soil bund	WOCAT: Alexandra/Boreda					X	X						X	X	X						x	X		x				X	x					X	X					X	X
Soil bund	WOCAT: Alexandra/Harergie-Harbo				X								X	X										x	x			X	x							X			X	X	
Graded Soil bund	WOCAT: Unknown/Hulet Eju Enese				X	X							X	X	X						x	X						X	x					X						X	X
Soil bund	WOCAT: Daniel Danano/Sorro, Ajacho				X	X								X	X	X					x			x					x	x											X
Stone bunds	Gizaw Desta																																								
Stone bunds	Belayneh Adugna			X	X							X	X	X	X	X								x				x							X	X			X	X	
level stone bund	WOCAT: Sabina/maybar					X									X									x			x		x												X
Stone bunds	WOCAT: Alexandra/Tigray-Enderta			X								X	X		X									x				x	x					X	X					X	
Stone bunds	WOCAT: Unknown/Dejen					X								X	X	X						x		x			x	x						X	X				X		
Stone bunds	WOCAT: Eva/North Shewa				X	X									X									x					x						X					X	X
Stone bunds	WOCAT: Unknown/Harargie-Jalela				X	X								X	X									x	x			x	x						X					X	X
Stone faced soil bunds	Gizaw Desta																																								
Stone faced soil bunds	Belayneh Adugna		X	X	X							X	X	X	X						X				x	x			x	x					X	X			X	X	
Stone faced level bund	WOCAT: Unknown/Chiro				X	X									X	X							x	x			x	x							X	X			X		
Stone faced soil bund	WOCAT: Unknown/Ambassel				X										X	X							x					x							X	X			X	X	
Stone faced soil bund	WOCAT: Unknown/Gomit, mukur					X							X	X	X									x	x		x	x							X				X	X	
Stone faced soil bund	WOCAT: Unknown/Deder, Wabe					X									X	X								x	x			x					X							X	
Hillside ditches	Gizaw Desta																																								
Trenches	Gizaw Desta																																								
Trench	Belayneh Adugna	X	X	X									X	X	X	X					X			x					x	x	x				X	X	X		X	X	
Trench	WOCAT: Alexandra/Atsebi		X										X	X	X	X							x	x	x			X						X	X					X	
Trench	WOCAT: Alexandra/Tigray Adet-Naedir		X	X									X	X	X						X			x	x			X					X	X	X					X	
Deep Trench bunds	WOCAT: Eyasu Yazew/Tigray Kilt Awulalo		X	X									X		X						X			x						x	x			X	X					X	X
Micro-basins	Gizaw Desta																																								
Micro-basins	Belayneh Adugna				X								X	X	X						X				x	x	X	X							X	X	X		X	X	
	WOCAT:																																								
Tie-ridging	Gizaw Desta																																								
Tie-ridging	Belayneh Adugna	X	X	X	X						X	X	X								X				x	x			x	x	x				X	X			X	X	
	WOCAT:																																								
Contour plough	Gizaw Desta																																								

Marginal conditions